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Current Opinion in Environmental Sustainability

Editorial Overview: 1.5°C Climate change and urban areas

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Current Opinion in Environmental Sustainability

2018, **30**:iv–vi

For a complete overview see the Issue

http://dx.doi.org/10.1016/j.cosust.2018.07.004

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Even if all national commitments to reduce greenhouse gas emissions under the Paris Agreement, the so-called 'Nationally Determined Contributions' (NDCs), are fully implemented, there will be a gap of 16–19 GtCO2e between the 2030 expected emissions and where emissions should be at in order to stay on track to meet the political ambition of the agreement, that is, keeping warming below 1.5°C as compared to the pre-industrial era [1]. This is a substantial amount, given that the world has emitted 32 Gt Co2e from burning fossil fuels in 2017.

There is increasing attention to non-state actors as important players to help close this gap [2]. In 2016, UNEP pointed to the importance of this stakeholder group that could potentially halve the gap [3]. Within this, cities could play an important role. For instance, [4] have estimated that urban action could reduce emissions by as much as 3.7 Gt CO2e in 2030 [4]. However, these numbers are extremely uncertain, score in a broad range, and it is unclear how much of these reductions are already included in the NDCs. Cities and urban areas are, without doubt, key in the context of climate action, for many reasons. First, they are the powerhouses of economic activities and development: they generate app. 80% of global gross domestic product (GDP), and their population increases by 1.3 million each week [5]. This dynamic activity and development poses both a challenge and opportunity: while cities are responsible for app. three-quarters of CO_2 emissions from energy use and are expected to continue to grow with the rapid urbanization of the 21st century [5], fast development and turbulent activity also often offers opportunities for step changes and radical departures from the business-as-usual. Cities are also smaller and often more flexible units of action and governance that have in the past shown to be able to more flexibly demonstrate progress in mitigation and commitment to climate action than nation states or federations of states. Individual charisma and leadership can also play a larger role at the urban level [6] than at the national or federal ones. This gains special importance when national/federal leadership regarding climate commitments dwindles or is withdrawn. Finally, climate action in cities is also crucial because over half of the global population resides in urban areas, often exhibiting high population densities and thus a concentrated vulnerability to climate change impacts. But cities are not only the subject of these impacts — they themselves influence their own climate by major physical, chemical and ecological alterations of their environments.

In the context of the Paris Agreement's 1.5°C target, urban areas may gain new importance. This is because the more ambitious the climate goals, the pathways that are able to meet these targets increasingly rely on mitigation

or solar radiation management options that are socially, politically or environmentally controversial [7–9] such as large-scale bioenergy with carbon capture and storage (BECCS) or ocean fertilisation. Therefore upscaling existing best practices, increasing the ambition of existing plans, or identifying further mitigation opportunities that are integrally connected to other social, economic, environmental and political agendas, rather than compromising these, may be able to relieve some of the pressure on these more controversial measures needed to meet ambitious climate goals [10,11]. Many mitigation options and other climate actions in urban areas are associated with such co-benefits [12], for example, reduced congestion from modal shifts away from individual automobile transport reduces air pollution [13], wasted travel times and thus economic losses and improves health [14,15]. Better land use planning results in more connected and livable cities. Green and white infrastructure can also cool cities on hot days [16].

Although there is burgeoning discussion and perhaps also action related to climate change in urban areas and networks, established and evidence-based knowledge is limited about the impacts of these, the magnitude and size of these opportunities, their ingredients and enablers. [17] draw attention to the major gaps in relevant knowledge and call for upscaling research in the topic.

The purpose of this special issue is therefore to contribute to filling this gap through synthetizing recent developments in the science of climate change and urban areas in the context of the Paris Agreement's ambitious climate goal: keeping warming under 1.5°C. Collectively, the papers in this special issue focus on urban mitigation and adaptation aspects of a 1.5°C rise in global temperature. The majority of the papers [17] focus on mitigation, while only 3 focus on adaptation or vulnerability, and 2 focus on neither mitigation nor adaptation exclusively, but rather on governance and city networks. Decarbonizing the urban power supply is a key topic of concern. Whether the framing is to create low carbon, zero energy, or net negative cities, how we power our cities in the future will be an important component of urban mitigation of climate change, as shown by the papers by Kennedy *et al.*, Saheb *et al.*, and Teske *et al.* Yet, decarbonizing the energy supply will only go so far, as argued by Wiedenhofer *et al.*, whose article shows the need to incentivize low-carbon everyday living. In other words, consumption patterns matter.

Buildings are another key sector where mitigation potential is enormous, both in terms of their construction and operation. Many new programs are now underway to reduce energy use in buildings, including voluntary programs aimed at low-carbon buildings (see paper by van der Heijden *et al.*) and new standards for very high efficiency buildings (see paper by Grove-Smith *et al.*). In China, the concept of nearly zero energy buildings is gaining wide traction but their feasibility to achieve emissions savings is unclear (see paper by Xing *et al.*). There is also much optimism around deep decarbonization and creating resilient cities in developing countries. The articles by Lwasa *et al.* and Mulugetta *et al.* highlight the opportunities and challenges that LDC cities face in developing deep mitigation pathways. Although there is much attention to the building and energy sectors, as Park *et al.* point out, there are also opportunities for low carbon pathways through innovations in the information and communication technologies (ICT) sector.

Regardless of the sector or pathway, all cities will need to have the necessary governance, financing and human capital to design and implement these strategies. The paper by Gomez Echeverri provides an assessment of the investment needs of cities to achieve systemic transformations and highlights the significant barriers to the growth of much needed financing schemes. Gordon *et al.* and Bertoldi *et al.* point to the role of city networks in building capacity and knowledge, and Fuhr *et al.* underscores the importance of strong governance in achieving both mitigation or adaptation strategies.

From an adaptation perspective, it is clear that there will be significant urban health impacts of a warming world, as underscored by the articles by Mika *et al.* and Bartholy *et al.* Extreme events are likely to increase and shown in the article by Zhai *et al.*, megacities like those in China will need to develop strategies to cope with increasing risks.

One message is clear from the collection of articles: there are significant knowledge gaps in understanding how we will mitigate, manage, or adapt to a 1.5 d world. As the article by Lamb *et al.* shows, the majority of emissions research focuses on the supply side (e.g. buildings, urban form, transport), but significantly less is known about the demand side (e.g. consumption, behavior). There is much work ahead for the science community to fill these gaps in knowledge in the race against time.

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